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ScienceDirect

Procedia Manufacturing 3 (2015) 2690 – 2697

Procedia MANUFACTURING

6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

Towards understanding the influence of environmental distractors on pedestrian behavior

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Abstract

Although it is known that pedestrians' injury rate is associated with specific urban environments; to the best of our knowledge, no research had systematically explored the effect of environmental distractions on pedestrian's crossing behavior and safety. The goal of this experiment was to obtain preliminary exploration of environmental distractions that influence pedestrians of different age groups. Eight children aged 7-8, eight children aged 9-10 and twelve adults participated in the experiment that took place in an urban simulated environment in a semi-immersive virtual reality lab. Participants viewed 13 dynamic scenarios that illustrated typical road-side crossing situations. Each scenario included distractors, which were defined by five characteristics: proximity, height, prominence, context relativity and dynamicity. Participants were required to press a designated crossing button as fast as possible, if they felt it was safe to cross, then they were required to state which distractors they remembered out of a checklist. Finally they had to rate theirperceivedsafety of the crossing site. Close, high, prominent or dynamic distractors were more memorable. Scenarios crowded with distractors caused participants to rate the crossing site as less safe for crossing. Children aged 7-8 ranked the crossing sites as safer for crossing in comparison to the other age groups, and regardless of the number of distractors in the scenario. Unlike them, adults and children aged 9-10 showed more sensitivity to the number of distractors in the scene, and ranked the site as more dangerous for crossing when more distractors were visible. A preliminary classification of environmental distractors, according to their influence on pedestrians' attention and with regard to their age group was created.

Peer-review under responsibility of AHFE Conference

*Keywords:*Distractions; Pedestrian; Child pedestrian; Road crossing; Environment

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Peer-review under responsibility of AHFE Conference
doi:10.1016/j.promfg.2015.07.659

1. Introduction

Pedestrians and child-pedestrians are subject to an increasing number of stimuli and distractions that are derived from either the surrounding urban environment, or their own activities. The negative effect of distraction on pedestrian safety was explored to an extant with the use of hand held cell-phones. Cell phone conversations' effect on pedestrian and driver behavior arerelatively explored research fields, and decision makers around the world have already issued practical guidelines and regulations with this regard. With the increase in their popularity, people use wireless devices regardless of the risks involved. An observation study reported that 11%-13% of all pedestrians that cross the road in junctions used their cell-phone at the same time [1]. Another study observed a shift in pedestrians' behavior when talking on the cell phone; pedestrians tended to cross slower, paid less attention to oncoming traffic and were less likely to wait for traffic to stop [2].It is not just cell-phone use, in a field study, it has been found that 20% of the pedestrians were busy with another distracting activity while trying to cross the road, and only 13% of them crossed the road in a safe manner, by looking to the left and right [3]. The implications are evident. According to reported hospitals data,the number of cell-phone related injuries, among pedestrians, increases each year and already passed the number of phone related injuries among drivers[4].Controlled studies in an immersive virtual environment (VE) have also demonstrated the negative effect that cell-phone conversations have on pedestrians when crossing the road. Pedestrians who conversed on their phone while crossing, showed an increase in unsafe behaviors. They performed worse in crossing tasks, were less likely to cross the road safely, and were more likely to be hit by a car in the VE[5–8]. Their behavior was also influenced by the nature of the conversation;pedestrians that were busy with a complex cognitive phone conversation were less attentive to traffic [8], it took them longer to initiate the crossing [6], and they suffered a deterioration in situation awareness[5]. Very few studies of this nature were conducted with children. In a single study withyoung participants, 10 and 11 years-old that were using a cell phone paid less attention to traffic and acted in a risky manner. Younger participants and those who were measured as non-attentive and oppositional were more likely to be distracted by the cell-phone and as a consequencebe less attentive to traffic[9]. As it comes from these studies both adults and young pedestrians behavior can be shifted when busy with distracting tasks.

Still, not much has been done to examine the ability of environmental distractions to cause negative crossing behavior among pedestrians.Although, studies of this type have already been conducted with drivers, and concluded that external distraction (e.g. signs and billboards) can lead to unsafe driving [10].There are several studies thatdemonstratethe association ofcertain built environments withthe risk ofpedestrian-vehicular accidents[11–16]. In these studies pedestrian-vehicular crashes and injury severity were found to be correlatedwithgeneral attributes of the environment, such as land use.For example, commercial sites as well as high-density residential areas were reported to be positively associated with pedestrian-vehicular collision[16]. In a different report, secondary retail (where stores are located along the road) was the main land use type to be associated with child pedestrian casualties; it was also found that low density residential, educational sites and primary retail sites are positively associated with child pedestrian casualties[13].

Some of the studies look deeper into micro-scale features and characteristics of the built environment.Features like traffic volume and pedestrian activity, that can be contributing to the risk of pedestrian collision[11,13,14,17,18]. For example, volume of traffic has a significant impact on thenumber of casualties and the risk of getting hurt[14]. In the same study,it was also suggested that built environments can indirectly increase the total number of injured pedestrians; as built environments with mixed land use, greater density, and high transit supply are positively associated with pedestrian activity, which is positively associated with the number of injured pedestrians. However, these studies do not clearly establish whetherthe pedestrian-vehicular crashes are a matter of higher pedestrian-vehicular encounters or result from a change in the behavior of pedestrians, or both. Acontrolled experimental study, demonstrated how child-pedestrian's behavior changes when exposed to higher traffic volume; by choosing smaller crossing gaps, faster reaction, and shorter safety margin [19]. Essentially,this studydemonstrated that pedestrian-vehicle collisions are not only the result of greater exposure in certain environments; but rather, and more importantly, that the environment can affect pedestrians' behavior in a manner that exposes them to greater risk.However, the behavior change might not necessarily be the result of being distracted, as crossing the road in dense traffic also requires more patience and planning, which children of younger ages may lack.Specificallyit has been shown that before crossing, pedestrians of different age groups allocate their attention to the environment differently, and with respect to the circumstances of the road environment[20].

2. Aims and hypothesis

In light of the literature review, and the gap that exists in understanding how environmental characteristics affect pedestrians' crossing behavior in general and in particular among child pedestrians, weaim to explore how the constructof the urban environment affect pedestrians' road crossing behavior. We intend to establish preliminary understandingof elements in the built city that can influence pedestrians and in particular child pedestrians and in what manner. Elements that were defined as distractors (see 3.4), were aggregated to categories based on their characteristics, such as:prominence, proximity, dynamicity, context (relevance to the environment), and height above ground. In accordance to that, the first study hypothesis was thatclose, or prominent distractors that do not blend in the environment will have higher potential to influence pedestrians'perception of the environment, and by that influence their crossing behavior. The second hypothesiswas that larger numbers of distractors will effect pedestrian perception as well. In line with the aforementioned literature, the third hypothesis was that greater volume of entities in the environment will have the same effect. The fourth hypothesis relates to age group. It was expected, that in line with other studies that demonstrate age groups differences, primarilyexpressed bylower sensitivity of younger children (aged 7-8)to elements in the environment, such as parked cars or limited field of view[21], children aged 7-8 will demonstrate insensitive behavior to distractions, which will be different from the children aged 9-10and the adults that will show greater sensitivity and awareness to elements in the environment.

3. Method

3.1. *Participants*

Twenty-eight individuals participated in the experiment, 12 adults aged (average=26.4, SD=1.3) and 16 children. The children were divided into two separate age groups, eight children aged 7-8 (average=7.4, SD=0.6) and eight children aged 9-10 (average=9.7, SD=0.4). Adultparticipants were students in the Human factors engineering introductory class and received either a bonus credit to their grade or 30 NIS (approx. 10$). Children received an educational compensation equivalent to 30NIS.

3.2. *Dome facility*

The 3D Perception™ Dome consists of a 180 degrees cylindrical screen (radius of 3.5 meters) aligned with a very accurate projection system of three projectors and equipped with a multi-directional sound system. This setting allows measurement of the participants when watching pre-designed simulated scenarios of real life situation from the roadside environment without the risk of harm (Figure 1).

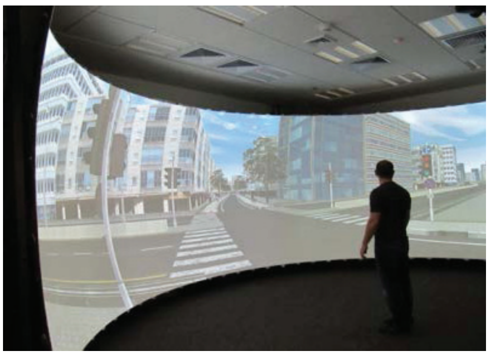

Fig. 1. The Dome facility with a participant standing in the center and viewing a scene from a pedestrian point of view.

3.3. *Distractors*

A distractor is an object in the scene that was presumed to draw more attention from the participant (e.g., a big commercial board) than other elements in the environment (e.g., benches and trees), even though there is no apparent need to attend to it for the crossing task. Traveling traffic was not defined as distractors, besides certain traveling prominent motor vehicles (e.g. a two story bus which is uncommon, an ambulance, etc.). Each one of the distractors in the scene was categorized by 5 binary characteristics: proximity to the participant's crossing point, height above ground, context (blends in the environment), prominence, and dynamicity. This means that a distracting object could be either close (up to 25 meters) or far, within eye-level or above it, prominent or not, and dynamic or static. Dynamic objects did not have to be in motion, flickering lights were also considered as dynamic.

3.4. *Scenarios*

During the experiment each participant observed a total of 13 urban typical scenarios and one training scenario, each 30-60 seconds long, from a pedestrian's point of view, i.e., as if they were pedestrians standing on one side of the pavement intending to cross the road over to the other side of a two lane street with a two-way traffic flow, as seen in Figure 2. The scenario database was built utilizing a three dimensional generic model of a typical city and the scenarios were constructed using VT MAK simulation applications. Environmental outdoor street sounds and traffic sounds were included in the scenario. Traffic flow was pre-defined by a random margin between adjacent travelling cars, and all vehicles travelled at a constant speed of 60 km/h. In each scenario, objects were embedded in the scene; a varying range of 0-21 objects that were predefined as distractors; and other objects and entities, such as benches, pergolas, vegetation, bus stops, vehicles, and people (varying range from 0 to over 200).

3.5. *Procedure*

Participants arrived atthe Dome lab on their own or accompaniedby aparent for an hour long session. All participants signed a consent form; parental consent was given for participants under the age of 18. All participants were tested for correct eye vision and got a short briefing to get familiar with the lab. Participants then were asked to fill a short demographic questionnaire. After getting particular instructions on the experiment they performed a training scenario in order to ensure that they understood the task. Participants then watched 13 dynamic scenarios on the Dome screen. Scenarios were projected from the perspective of a pedestrian aiming to cross the road.They were presented in a random order andwere distinguished from each otherby the type and number of distractions that were integrated in the road-side scene.Participantswereinstructed to press a designated green button whenever theyfelt it was safe to cross the road. After pressing the button or oncethe scenario ended, a checklist consisting of part of the distractorsthat wereapparent in the scenario and some elements that werenot presented, appeared on the dome screen.Participants then had to mark the distractorsthat theyremembered that wereapparent in the scene. After completion of the checklist,using a slide bar, the participant was asked to ratehis perceivedsafety,of the specific location, for road crossing. After watching all 13 scenarios, the experiment ended and the participant was released after getting the compensation.

3.6. *Independent - explanatory variables*

1. Load- the number of entities and objects (distractors or not) that were integrated in the scenario. Low load was defined as less than 100 entities and objects, medium load was defined as 100-200 entities and objects and over 200 entities and objects was consider as high load.
2. Number of distractors- the number of distractors (between 0-21), of any type, and that wereembedded in the scenario.
3. Distractor characteristics- each one of the distractors was categorized using 5 parameters: proximity, height above ground, context, prominence, and dynamicity (see 3.4).
4. Age group- participants from three age groups participated in the experiment, children aged 7-8, aged 9-10, and adults (see 3.1).

Fig. 2. The participant's field of view of the simulated scene in the virtual environment.For example here two distractors are marked: marked as 1- close, prominent, static, above eye-level, and in context to the environment type of object; marked as 2- close, prominent, dynamic, within eye-level, and in of context type of object.

3.7. *Measures*

1. Recall of distractors- the number of predefined distractors in the scenario that were remembered by the participant and marked on the checklist, completed at the end of each scenario.
2. Safety rate- a subjective evaluation given by the participant, on a scale of 0-100, upon the safety of the location of crossing (0 being non safe at all and 100 being the safest).

4. Results

In the analysis of the recalling task (4.1) a logistic regression within the general linear mixed model (GLMM) frame work was applied; in the safety rating task (4.2) a linear mixed model (LMM) was applied. In both analyses, participants were included as a random effect to account for individual differences among participants and the final model was archived using the backward elimination procedure.

4.1. *Recalling distractors based on the checklist*

The full logistic regression model included the following fixed effect: age group, and the five defined distractor characteristics: context, height above ground, proximity, dynamism, and prominence, and the interactions of age group with the five characteristics. Using a backward elimination procedure, age group ($F_{2,1767}$=3.47, Sig.=.031) and the distractor's height above ground ($F_{2,1767}$=3.47, Sig.=.031), proximity ($F_{1,1767}$=24.35, Sig.<.001), dynamicity ($F_{1,1767}$=73.34, Sig.<.001), and prominence ($F_{1,1767}$=80.45, Sig.<.001) all had a significant effect on the probability that a participant will be able to recall a certain distractor, after the scenario has ended.

According to the final model ($F_{6,1767}$=25.27, Sig.<.001), the estimated probability to recall a distractor correctly, after the scenario has ended, was highest when it was prominent, and it was then recalled in 67.8% of the cases. This estimated rate is 38.1% higher than the opposite case when the object was not prominent.Second best was when the object was dynamic, then it was recalled correctly in 62.6% of all cases, with a meaningful contrast of 27.9% from objects that were non-dynamic.Object height above ground also played a role, when it was above eye level the chances to be recalled were 21.1% higher than when it was at eye level. The least meaningful difference between two contradictory modes was 16.3%, between when the object was closeto when it wasfar.Figure 3 presents the estimated recalling rate of distractors according to their characteristics.

In order to neutralized confounding effects of 'over marking', a situation where participants mark objects from the list "just in case" they actually where present, even though they do not remember them, an analysis of 'correct rejections' was done. Age group was set to be the explanatory variable of the model. The mean 'correct rejections' rate was 0.95 for the adults, 0.89 for the children aged 9-10 and 0.87 for the children aged 7-8, with no statistically

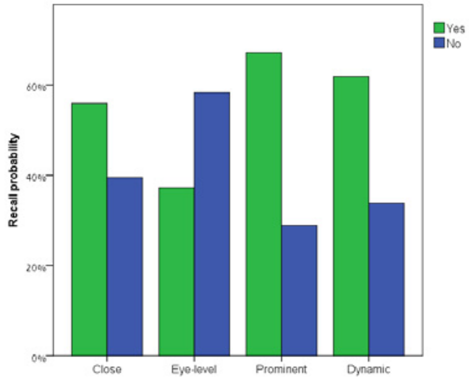

Fig.3. The estimated probability of recalling a distracting object in accordance to its characteristics, as they werederived from the regression model.

significant differences among the groups. These results indicate that none of the groups 'over marked' the checklist, and that they all behaved in a similar manner, as the model for ‘correct rejections’ was insignificant ($F_{2,329}$=1.42, Sig.=.244).

Although age group did not have any interactions with object characteristics, still some differences could be seen among the age groups. Figure 4 illustrates a regression model that included only the four interactions of age group; Figure 4 illustrates clearly that no interaction of age group with other factors came out statistically significant. However, from looking at Figure 4, it can be seen that the youngest age group, aged 7-8, have slightly smaller gaps between the two contradictory modes of characteristics. The most meaningful interaction (although not statistically significant) was with the proximity of the object; the children aged 7-8 were the only group that had insignificant difference between the probability of recalling close and far objects (Figure 4 (b)).

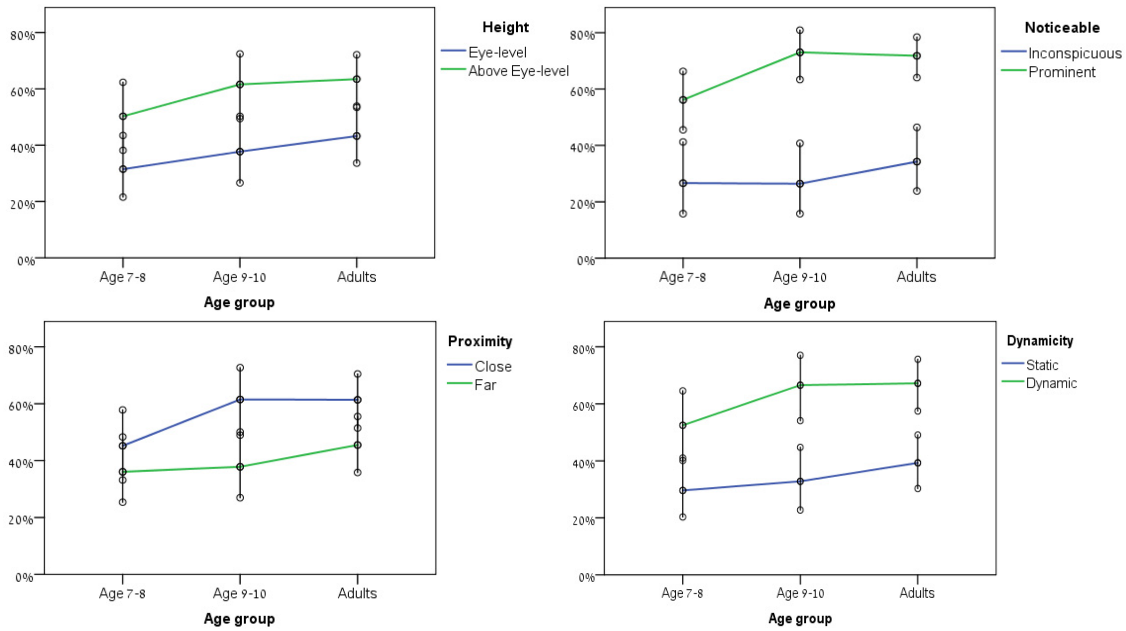

Fig.4. The estimated means of recalling probabilities from the interaction regression model. The significance of differences between pairs of groups was tested with the LSD at level of 0.05. Interaction of age group with the: (a) dynamicity; (b) proximity; (c) prominence; and (d) eye-level of the object.

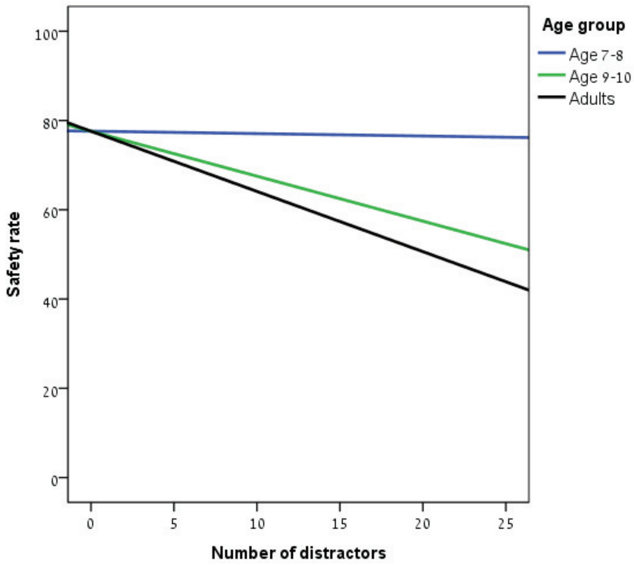

Fig.5. Regression lines of the interaction of age group and number of distractorsas derived from the final regression model.

4.2. *Safety rating of dynamic scenarios*

The full model used to explain the subjective safety rating included the load in the scenario, number of distractors, age group, the five distractor's characteristics, and the two interactionsof age group with load and number of distractors. The final model after applying a backward elimination included the number of distractors ($F_{1,316}$=21.79, Sig.<.001) as well as the interaction of number of distractors and age group ($F_{2,316}$=5.94, Sig.=.003). As seen in Figure 5, the overall trend was that higher number of distractors in the scene, caused participants to estimate the place as less safe for crossing.The results show that the adults ($\hat{\beta}$=–1.35, SE=.25, Sig.<.001) as well as the children aged 9-10 ($\hat{\beta}$=–1.01, SE=.29, Sig.=.001) estimated the place as safer for crossing as the number of distractors was lower. In contrast to them, the estimation of safety of the crossing place for children aged 7-8 ($\hat{\beta}$=–.054, SE=.30, Sig.=.86) was not dependent on the number of distractors, as it seen from the regression line in Figure 5.

5. Discussion

As it stems from this experiment, objects that are characterized in a certain manner tend to be recalled more often than others. Close, prominent, above eye level, and dynamicity were characteristics that raised the probability of an object to be recalled by the participant.Context was not meaningful enough to explain the participants' way of recalling; neither of the distractors' characteristics was significant enough to explain the way that participants' evaluated the safety of the crossing location. Their safety evaluation mainly relates to their agegroup and was based on the number of distractors; children aged 9-10and adults evaluated the crossing location as less safe as the number of distractors was higher. Children aged 7-8 were oblivious to the changes in the environment,as was expressed in the way they rated the safety of acrossing place. This behavior in children aged 7-8 is recognized from previous studies [21] and in line with the assumptions of this study. In fact, it is not clear what will cause children aged 7-8 to rate the crossing places differently, as on average they rated all of the scenarios in the same way.

The load in the scenario, as it was defined, did not have any influence on the way that participants evaluated the safety of the crossing place, in contrast to the study hypothesis. Although age differences were existent in the safety evaluation of the crossing place, it seems that for all ages, participants' attention was drawn to similar types of objects in the environment, as we assume is reflected by their ability to recall an object and focus on it.The findingsof this experiment layout an initial understanding of the types of objects and therebyenvironments, which may pose higher risk to pedestrians and particularly to less capable, children pedestrians. Thus, crossing behavior is affected by the objects and overall construction of distractors in the environment. This experiment also highlights the fact that young children aged 7-8 are not able to evaluate all the risks that the environment poses to them, in contrary to older children and adults. The results can be in used for urban designers, and policy makers, in order to keep in mind the negative effects that environmental distractors might have on adults and especially on young pedestrians.Parents and road-safety educators that guide and shape children road behavior should also be aware of the implications of environmental distractions.

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